Cold Plasma in the Earth's Magnetosphere

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Dominated by the terrestrial magnetic field and largely excluding the solar wind, the magnetosphere is a vast region surrounding the Earth in which populations of hot and cold ionized gases or plasmas carry mass away from the upper atmosphere and carry energy back. The processes of energy and particle transport ultimately lead to solar heating and convection in the Earth's ionosphere. One element of such processes studied in MSFC's Space Plasma Physics Branch is the population of cold plasmas that originate in the ionosphere. These cold plasmas include singly ionized hydrogen, helium, oxygen, and molecular ions, and doubly ionized helium and oxygen.

Cold plasmas dominate other hotter plasmas in the inner magnetosphere by their number and mass. Further, they directly influence many of the dynamic processes important in this environment. Energy carried by waves inward toward the Earth can be excluded from, or admitted to, low altitudes as a result of the density and composition of cold plasmas. Energetic particles trapped in the Earth's magnetic field can be released into the ionosphere or allowed to escape out into the magnetosphere through interactions with cold plasmas.

Although the ultimate goal of researchers is to develop a theoretical understanding of the many processes important in the magnetosphere, the path to this understanding is through measuring the properties of plasmas and assembling these many thousands of measurements into coherent pictures of our local space environment. The development of empirical, or data-based, models of our terrestrial cold plasma environment is an important part of the activities leading to accomplishing the overall goal.

Many measurements of plasma density, composition, and temperature have been made by MSFC and other researchers in the inner magnetosphere over the more than 30 years of instrumented spacecraft operations in orbit about the Earth. MSFC researchers have used measurements from the Retarding Ion Mass Spectrometer onboard the Dynamics Explorer 1 spacecraft to characterize cold plasmas near the Earth. Descriptions of such measurements have been organized by space weather conditions and position in space to allow for the development of mathematical equations that can be used to represent conditions in the space environment. These mathematical descriptions, or empirical models, have now been combined with similar models produced by other researchers for complementary conditions and locations to synthesize a more complete global model of cold plasma density. (Figure 26 is a graphical presentation of plasma density as a function of position corresponding to steady, moderately active space weather conditions. Density is coded in gray-scale intensity, with the lightest shading corresponding to the highest densities.) New to this type of model development is the incorporation of high-latitude and low-altitude plasma densities. At low altitude, the new empirical model is joined to the International Reference Ionosphere model, which is itself a global, empirical model of densities, composition, and temperature in the ionosphere that has been developed as an international cooperative effort.

As discussed earlier, the development of a global, empirical model of cold plasma densities in near-Earth space is a key step in the search for a deeper understanding of the physical processes important in the transport of the Sun's energy to the Earth. Empirical models, such as what is being developed, are used to guide and test theories for how nature works in this region. Computer simulations of space plasma processes also benefit from the use of empirical models by allowing researchers to employ realistic descriptions of the space environment, which greatly improve the accuracy of their predictions for conditions in space.

Beyond the purely scientific applications, however, there are many practical applications of these empirical modeling results. Critical to the success of modern telecommunication and research satellites is the ability to reliably predict the conditions in space in which satellites will operate. Ionizing radiation can penetrate sensitive electronic components, either causing damage or disrupting onboard computers. Satellites designed with electrically insulating surfaces are susceptible to high-voltage charging in space plasmas. Voltages can easily become high enough to break down insulators, causing electric discharging and physical damage to the spacecraft. Low cold plasma densities tend to

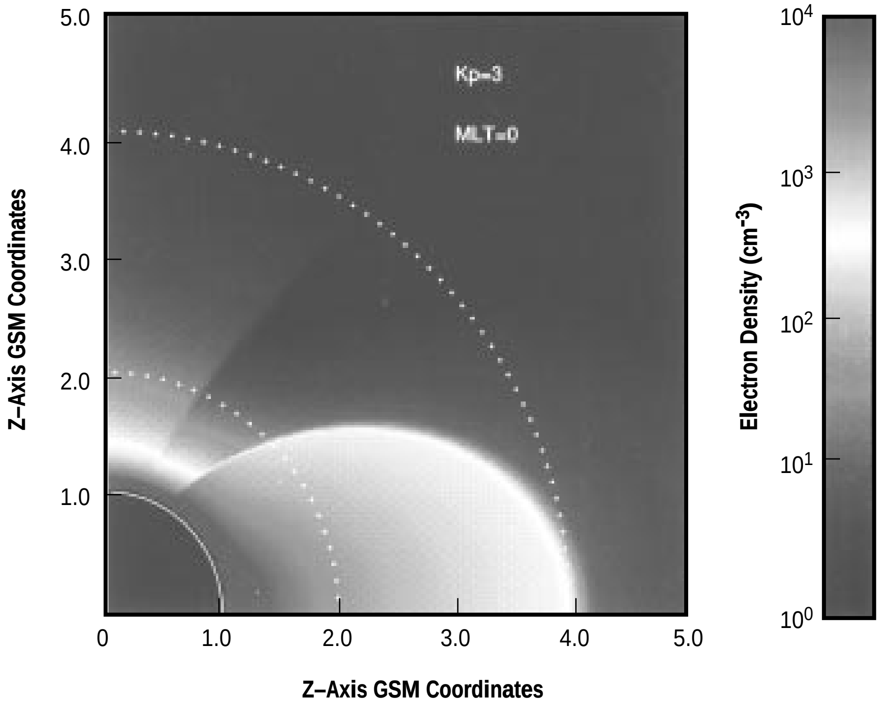

FIGURE 26.—Plasma density as a function of position.

allow spacecraft charging, while high cold plasma densities tend to reduce the severity of ionizing radiation populations.

Accurate representations of cold plasma densities also play a role in designing better radio communication, such as through the global positioning system. This system, which can be used on aircraft, boats, and cars, is a system of satellites in orbit around the Earth that broadcast radio signals used to accurately determine the position of receiving stations on the surface of the Earth. These satellite receivers are even small enough for individuals to carry and operate off of batteries. Variations in cold plasma density act as noise to these navigational signals, which reduces the accuracy in determining receiver position. Accurate modeling of cold plasma densities can be used to predict global positioning system-receiver accuracy and possibly improve future designs.

More than 30 years of spacecraft observations of the Earth's natural space environment has led to the development of empirical models of a variety of regions and plasma populations. Research in the Space Plasma Physics Branch has resulted in the synthesis of a global, empirical model of near-Earth cold plasma densities. The steady-state descriptions given by this modeling provide density as a function of position, solar luminosity, and local space weather conditions. Modeling results will be used to better understand the volatile processes going on in space plasmas and to better design and operate manmade systems in space.

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